CONTACTS FOR AN N-TYPE GALLIUM AND NITROGEN SUBSTRATE FOR OPTICAL DEVICES

FIELD

The present invention relates to techniques for manufacturing optical devices. More particularly, the present invention includes light emitting diodes and in particular to ohmic contacts for light emitting diodes.

BACKGROUND

A metric for the efficiency of light emitting diodes (LEDs) is the luminance per watt. The luminance provided by light emitting diodes is dependent upon several factors, such as internal quantum efficiency, which quantifies the fraction of injected carriers converted to photons, or extraction efficiency, which quantifies the fraction of photons successfully extracted from the light emitting diode. Internal absorption may prevent photons from escaping the light emitting diode. To realize high efficiency LEDs, both the internal efficiency and extraction efficiency should be addressed. The potential gains from improving extraction efficiency, however, are likely to be greater and simpler to accomplish than the gains from improving internal efficiency.

From the above, it is seen that improved techniques for manufacturing optical devices are highly desired.

SUMMARY

In an example, the present invention provides a method for fabricating LED devices. The method includes providing a gallium and nitrogen containing substrate member (e.g., GaN) comprising a backside surface and a front side surface. The front side surface includes an n-type material overlying the substrate member, an active region overlying the n-type member, and a p-type material overlying the active region. The method includes subjecting the backside surface to a polishing process, causing a backside surface characterized by a surface roughness. The method also includes subjecting the backside surface to an anisotropic etching process exposing various crystal planes to form a plurality of pyramid-like structures distributed spatially in a non-periodic manner on the backside surface. The method includes treating the backside surface, comprised of a plurality of pyramid-like structures, to a plasma species, and subjecting the backside surface to a surface treatment. The method forms a contact material comprising an aluminum bearing species or a titanium bearing species overlying the surface-treated backside to form a plurality of LED devices with the contact material.

Various additional objects, features and advantages of the present invention can be more fully appreciated with reference to the detailed description and accompanying drawings that follow.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a simplified diagram of an n-type c-plane GaN substrate with epitaxial LED structure (n-layer, active region, p-layer) according to an embodiment of the present invention.

FIG. **2** illustrates polishing of n-type layer with diamond slurry until optically smooth (RMS surface roughness 100 nm or less) according to an embodiment of the present invention.

FIG. **3** is a substrate with optically smooth nitrogen face of c-plane GaN prepared by polishing or lapping and polishing according to an embodiment of the present invention.

FIG. **4** is an n-GaN surface roughened by exposure to a solution of silicic acid hydrate, potassium hydroxide (KOH), and water according to an embodiment of the present invention.

FIG. **5** is a scanning electron microscope image of roughened n-GaN surface after exposure to solution of silicic acid hydrate, KOH and water according to an embodiment of the present invention. In FIG. **5**, the distance from the leftmost marker to the rightmost marker is 10 μm.

FIG. **6** is a simplified n-GaN surface etched by $SiCl_4$ plasma according to an embodiment of the present invention.

FIG. **7** is an illustration of a photoresist-patterned substrate treated with an oxygen plasma, followed by a $SiCl_4$ plasma treatment (when the n-contacts will be patterned using a lift-off process) according to an embodiment of the present invention.

FIG. **8**A and FIG. **8**B illustrate a process for HCl treatment of an n-GaN surface, with (FIG. **8**A) or without (FIG. **8**B) patterned photoresist according to an embodiment of the present invention.

FIG. **9**A and FIG. **9**B are illustrations of metal layers deposited on the n-GaN surface (the stack begins with a first layer of Al or Ti, followed by a barrier layer) according to embodiments of the present invention.

FIG. **10** illustrates a resulting substrate structure where solvents are used to remove photoresist and unwanted metal in a liftoff process according to an embodiment of the present invention.

FIG. **11** illustrates a process for treatment of metal annealed to reduce the contact resistance according to an embodiment of the present invention.

FIGS. **12** through **16** illustrate images of roughened surface regions, including pyramidal structures, according to embodiments of the present invention. In FIGS. **12-14**, the distance from the leftmost marker to the rightmost marker is 10 μm. In FIG. **15**, the distance from the leftmost marker to the rightmost marker is 5 μm. In FIG. **16**, the distance from the leftmost marker to the rightmost marker is 2 μm.

FIG. **17** illustrates one example of measured current as a function of voltage between aluminum contacts on n-GaN with the treatments described, compared to contacts to an untreated n-GaN surface.

DETAILED DESCRIPTION

The present invention relates to techniques for manufacturing optical devices. More particularly, the present invention includes light emitting diodes and in particular, ohmic contacts for light emitting diodes. Such light emitting devices can include LEDs, lasers and the like. Progress has been made during the past decade and a half in the performance of gallium nitride (GaN) based light emitting diodes (LEDs). Devices with a luminous efficiency greater than 100 lumens per watt have been demonstrated in the laboratory, and commercial devices have an efficiency that is already considerably superior to that of incandescent lamps, and competitive with fluorescent lamps. Further improvements in efficiency can reduce operating costs, reduce electricity consumption, and decrease emissions of carbon dioxide and other greenhouse gases produced in generating the energy used for lighting applications.

As background information, we have observed that conventional GaN-based light emitting diodes (LED) emitting in the ultraviolet and visible regions are based on heteroepitaxial growth where growth is initiated on a substrate other than GaN such as sapphire, silicon carbide, or silicon. This is due to the limited supply and high cost of free-standing GaN